

# ***Exhibit 11***

Exhibit 11  
Claim 15 of U.S. Patent No. 10,965,512

"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

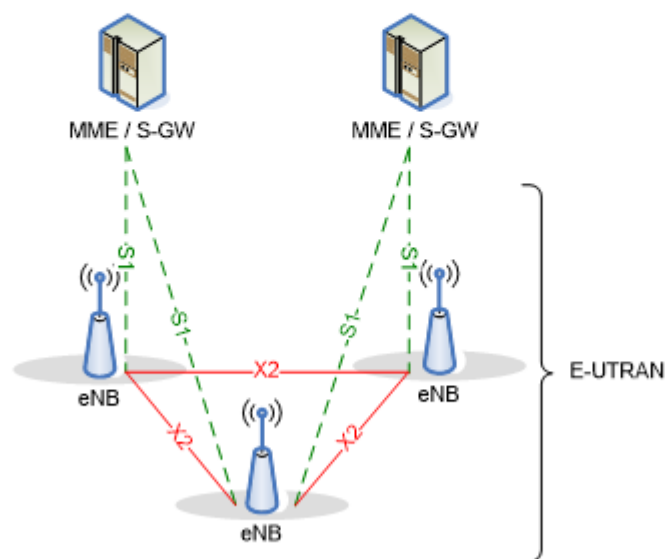
15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:	<p>Ford's Accused Products include vehicles equipped with components and/or devices that enable connectivity to 4G/LTE networks and services, including services sold and provided by Ford.</p> <p>To the extent the preamble is considered a limitation, Ford's Accused Products meet the preamble of the '512 patent. <i>E.g.</i>,</p> <p>The LTE release 8 standard and subsequent releases ("LTE") include an orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain.</p> <p>For example, the LTE specification (Series 36, Release 8) supports user equipment (UEs) to communicate with eNodeBs.</p>
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"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

## 4 Overall architecture

The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core), more specifically to the MME (Mobility Management Entity) by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / Serving Gateways and eNBs.

The E-UTRAN architecture is illustrated in Figure 4 below.



**Figure 4-1: Overall Architecture**

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 15.

LTE uses OFDMA in the downlink transmission.

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## 5.1 Downlink Transmission Scheme

### 5.1.1 Basic transmission scheme based on OFDM

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix. The OFDM sub-carrier spacing is  $\Delta f = 15$  kHz. 12 consecutive sub-carriers during one slot correspond to one downlink *resource block*. In the frequency domain, the number of resource blocks,  $N_{RB}$ , can range from  $N_{RB-min} = 6$  to  $N_{RB-max} = 110$ .

In addition there is also a reduced sub-carrier spacing  $\Delta f_{low} = 7.5$  kHz, only for MBMS-dedicated cell.

In the case of 15 kHz sub-carrier spacing there are two cyclic-prefix lengths, corresponding to seven and six OFDM symbols per slot respectively.

- Normal cyclic prefix:  $T_{CP} = 160 \times T_s$  (OFDM symbol #0),  $T_{CP} = 144 \times T_s$  (OFDM symbol #1 to #6)
- Extended cyclic prefix:  $T_{CP-e} = 512 \times T_s$  (OFDM symbol #0 to OFDM symbol #5)

where  $T_s = 1 / (2048 \times \Delta f)$

In case of 7.5 kHz sub-carrier spacing, there is only a single cyclic prefix length  $T_{CP-low} = 1024 \times T_s$ , corresponding to 3 OFDM symbols per slot.

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 25.

Each frame structure has time slots. For example, Frame structure type 1 for FDD includes 20 time slots.

## 4.1 Frame structure type 1

Frame structure type 1 is applicable to both full duplex and half duplex FDD. Each radio frame is

$T_f = 307200 \cdot T_s = 10$  ms long and consists of 20 slots of length  $T_{slot} = 15360 \cdot T_s = 0.5$  ms, numbered from 0 to 19. A subframe is defined as two consecutive slots where subframe  $i$  consists of slots  $2i$  and  $2i+1$ .

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For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. In half-duplex FDD operation, the UE cannot transmit and receive at the same time while there are no such restrictions in full-duplex FDD.

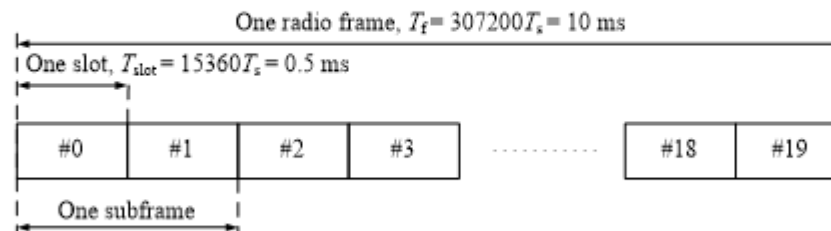


Figure 4.1-1: Frame structure type 1.

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 9-10.

The mobile station receives signals in the form of subcarriers having a time domain and frequency domain component.

### 6.2.1 Resource grid

The transmitted signal in each slot is described by a resource grid of  $N_{RB}^{DL} N_{sc}^{RB}$  subcarriers and  $N_{symb}^{DL}$  OFDM symbols.

The resource grid structure is illustrated in Figure 6.2.2-1. The quantity  $N_{RB}^{DL}$  depends on the downlink transmission bandwidth configured in the cell and shall fulfil

$$N_{RB}^{min, DL} \leq N_{RB}^{DL} \leq N_{RB}^{max, DL}$$

where  $N_{RB}^{min, DL} = 6$  and  $N_{RB}^{max, DL} = 110$  are the smallest and largest downlink bandwidth, respectively, supported by the current version of this specification.

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The set of allowed values for  $N_{RB}^{DL}$  is given by [6]. The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured and is given in Table 6.2.3-1.

In case of multi-antenna transmission, there is one resource grid defined per antenna port. An antenna port is defined by its associated reference signal. The set of antenna ports supported depends on the reference signal configuration in the cell:

- Cell-specific reference signals, associated with non-MBSFN transmission, support a configuration of one, two, or four antenna ports and the antenna port number  $p$  shall fulfil  $p = 0$ ,  $p \in \{0,1\}$ , and  $p \in \{0,1,2,3\}$ , respectively.
- MBSFN reference signals, associated with MBSFN transmission, are transmitted on antenna port  $p = 4$ .
- UE-specific reference signals are transmitted on antenna port  $p = 5$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 45.

## 6.2.2 Resource elements

Each element in the resource grid for antenna port  $p$  is called a resource element and is uniquely identified by the index pair  $(k, l)$  in a slot where  $k = 0, \dots, N_{RB}^{DL} N_{sc}^{RB} - 1$  and  $l = 0, \dots, N_{symb}^{DL} - 1$  are the indices in the frequency and time domains, respectively. Resource element  $(k, l)$  on antenna port  $p$  corresponds to the complex value  $a_k^{(p)}$ . When there is no risk for confusion, or no particular antenna port is specified, the index  $p$  may be dropped.

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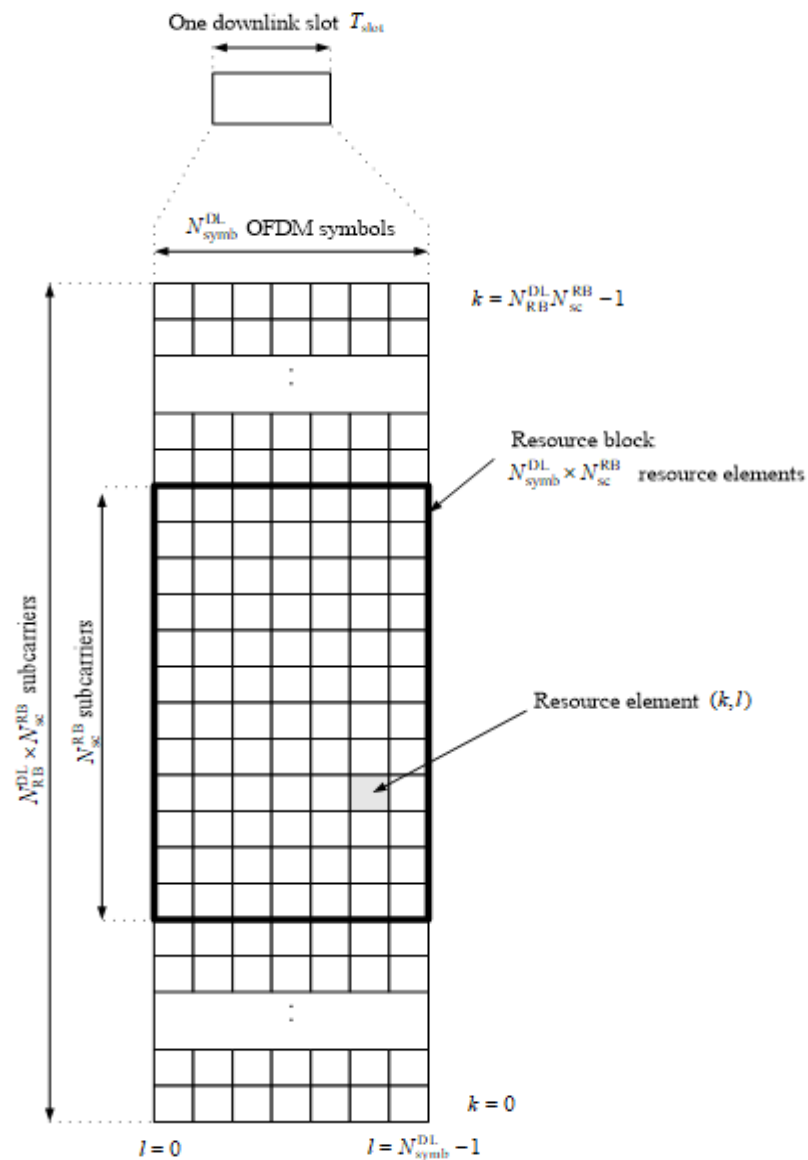


Figure 6.2.2-1: Downlink resource grid.

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 45-46.



"15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

A physical resource block (PRB) corresponds to a plurality of consecutive OFDM symbols in the time domain and a plurality of consecutive subcarriers in the frequency domain, which correspond to a block of resource elements. The block of resource elements correspond to one time slot in the time domain and 180 kHz in the frequency domain.

### 6.2.3 Resource blocks

Resource blocks are used to describe the mapping of certain physical channels to resource elements. Physical and virtual resource blocks are defined.

A physical resource block is defined as  $N_{\text{symp}}^{\text{DL}}$  consecutive OFDM symbols in the time domain and  $N_{\text{sc}}^{\text{RB}}$  consecutive subcarriers in the frequency domain, where  $N_{\text{symp}}^{\text{DL}}$  and  $N_{\text{sc}}^{\text{RB}}$  are given by Table 6.2.3-1. A physical resource block thus consists of  $N_{\text{symp}}^{\text{DL}} \times N_{\text{sc}}^{\text{RB}}$  resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

Physical resource blocks are numbered from 0 to  $N_{\text{RB}}^{\text{DL}} - 1$  in the frequency domain. The relation between the physical resource block number  $n_{\text{PRB}}$  in the frequency domain and resource elements  $(k, l)$  in a slot is given by

$$n_{\text{PRB}} = \left\lfloor \frac{k}{N_{\text{sc}}^{\text{RB}}} \right\rfloor$$

**Table 6.2.3-1: Physical resource blocks parameters.**

Configuration		$N_{\text{sc}}^{\text{RB}}$	$N_{\text{symp}}^{\text{DL}}$
Normal cyclic prefix	$\Delta f = 15 \text{ kHz}$	12	7
	$\Delta f = 15 \text{ kHz}$		6
Extended cyclic prefix	$\Delta f = 7.5 \text{ kHz}$	24	3

See e.g., 3GPP TS 36.211 V8.9.0 at pgs. 46-47.

- "15. An orthogonal frequency division multiple access (OFDMA)-compatible mobile station that uses subcarriers in a frequency domain and time slots in a time domain, the OFDMA-compatible mobile station comprising:"

## 6.12 OFDM baseband signal generation

The time-continuous signal  $s_i^{(p)}(t)$  on antenna port  $p$  in OFDM symbol  $l$  in a downlink slot is defined by

$$s_i^{(p)}(t) = \sum_{k=-\lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor}^{-1} a_{k^{(-)},i}^{(p)} \cdot e^{j2\pi k \Delta f (t - N_{CP,l} T_s)} + \sum_{k=1}^{\lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor} a_{k^{(+)},i}^{(p)} \cdot e^{j2\pi k \Delta f (t - N_{CP,l} T_s)}$$

for  $0 \leq t < (N_{CP,l} + N) \times T_s$  where  $k^{(-)} = k + \lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor$  and  $k^{(+)} = k + \lfloor N_{RB}^{DL} N_{sc}^{RB}/2 \rfloor - 1$ . The variable  $N$  equals 2048 for  $\Delta f = 15$  kHz subcarrier spacing and 4096 for  $\Delta f = 7.5$  kHz subcarrier spacing.

The OFDM symbols in a slot shall be transmitted in increasing order of  $l$ , starting with  $l = 0$ , where OFDM symbol  $l > 0$  starts at time  $\sum_{l'=0}^{l-1} (N_{CP,l'} + N) T_s$  within the slot. In case the first OFDM symbol(s) in a slot use normal cyclic prefix and the remaining OFDM symbols use extended cyclic prefix, the starting position the OFDM symbols with extended cyclic prefix shall be identical to those in a slot where all OFDM symbols use extended cyclic prefix. Thus there will be a part of the time slot between the two cyclic prefix regions where the transmitted signal is not specified.

Table 6.12-1 lists the value of  $N_{CP,l}$  that shall be used. Note that different OFDM symbols within a slot in some cases have different cyclic prefix lengths.

**Table 6.12-1: OFDM parameters.**

Configuration		Cyclic prefix length $N_{CP,l}$
Normal cyclic prefix	$\Delta f = 15$ kHz	160 for $l = 0$
		144 for $l = 1, 2, \dots, 6$
Extended cyclic prefix	$\Delta f = 15$ kHz	512 for $l = 0, 1, \dots, 5$
	$\Delta f = 7.5$ kHz	1024 for $l = 0, 1, 2$

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 76.

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"

at least one antenna; and  
 a receiver; and  
 the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;

Ford's Accused Products each include at least one antenna and a receiver, wherein the at least one antenna and the receiver are configured first and second pilots of first and second types, respectively. *E.g.*,

The UE receives first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots and receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots.

For example, the LTE UE receives cell-specific reference signals and UE-specific reference signals via at least one antenna on a plurality of subcarriers in at least one time slot.

## 5 Physical Layer for E-UTRA

Downlink and uplink transmissions are organized into radio frames with 10 ms duration. Two radio frame structures are supported:

- Type 1, applicable to FDD,
- Type 2, applicable to TDD.

Frame structure Type 1 is illustrated in Figure 5.1-1. Each 10 ms radio frame is divided into ten equally sized subframes. Each sub-frame consists of two equally sized slots. For FDD, 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain.

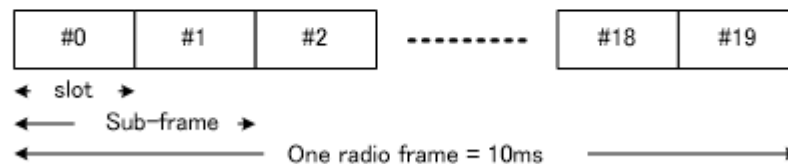


Figure 5.1-1: Frame structure type 1

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 23.

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of  
 subcarriers are received in at least one of the time slots;"

## 6.10 Reference signals

Three types of downlink reference signals are defined:

- Cell-specific reference signals, associated with non-MBSFN transmission
- MBSFN reference signals, associated with MBSFN transmission
- UE-specific reference signals

There is one reference signal transmitted per downlink antenna port.

See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

The mapping of the cell-specific reference signals are to resource elements that correspond to a subcarrier and symbol in a slot.

### 6.10.1 Cell-specific reference signals

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for  $\Delta f = 15 \text{ kHz}$  only.

See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of  
 subcarriers are received in at least one of the time slots;"

### 6.10.1.2 Mapping to resource elements

The reference signal sequence  $r_{l,n_s}(m)$  shall be mapped to complex-valued modulation symbols  $a_{k,l}^{(p)}$  used as reference symbols for antenna port  $p$  in slot  $n_s$  according to

$$a_{k,l}^{(p)} = r_{l,n_s}(m')$$

where

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symbol}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0, 1, \dots, 2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + N_{\text{RB}}^{\text{max,DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables  $v$  and  $v_{\text{shift}}$  define the position in the frequency domain for the different reference signals where  $v$  is given by

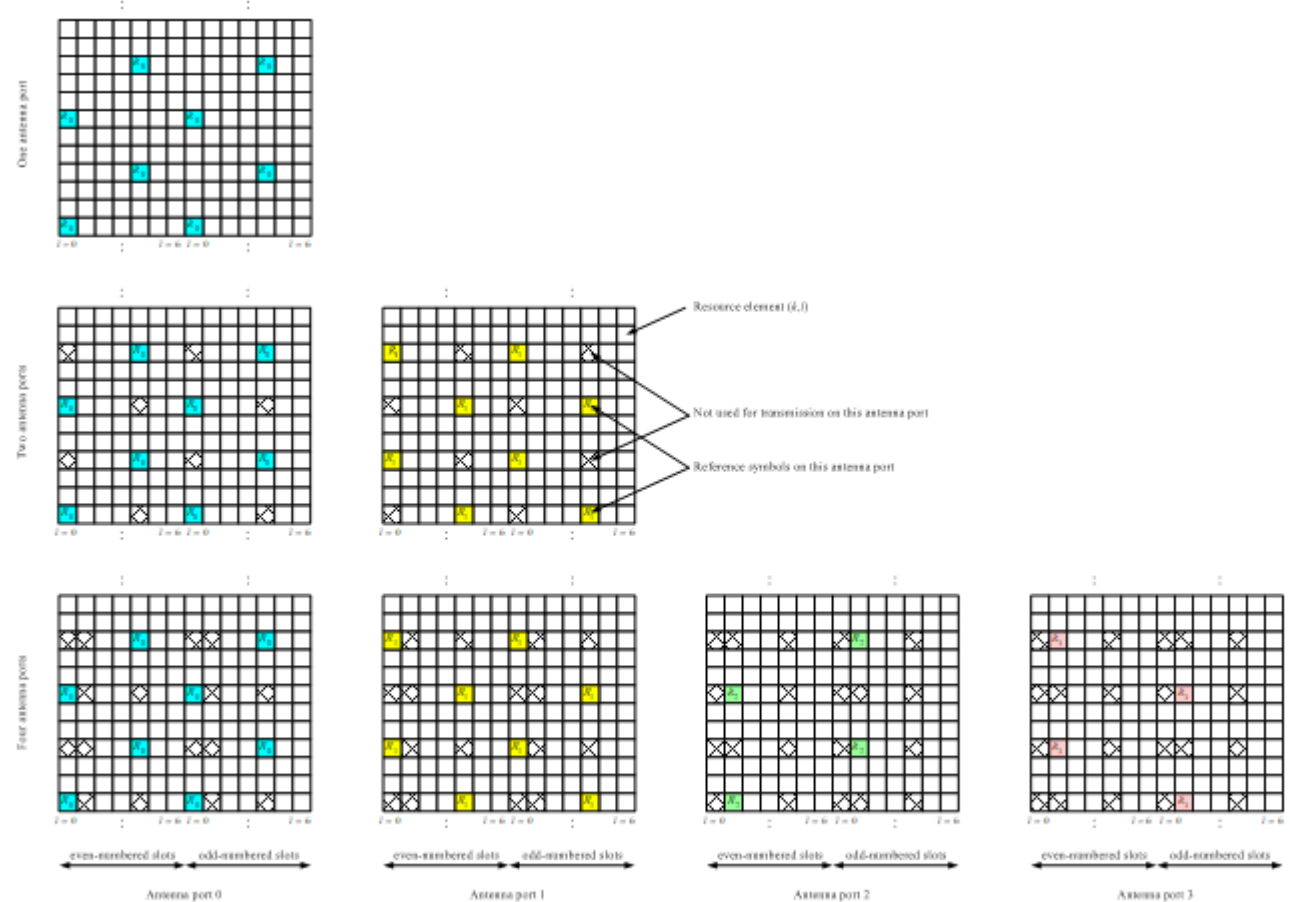
$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_s \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_s \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by  $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$ .

Resource elements  $(k, l)$  used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation  $R_p$  is used to denote a resource element used for reference signal transmission on antenna port  $p$ .

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of subcarriers are received in at least one of the time slots;"



**Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).**

See e.g., 3GPP TS 36.211 V8.9.0 at pg.66-67.

The UE-specific reference signals are transmitted on resource elements, which include the second plurality of subcarriers, upon which a corresponding PDSCH, data, is mapped.

### 6.10.3 UE-specific reference signals

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of  
 subcarriers are received in at least one of the time slots;"

UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements  $(k, l)$  in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair  $(k, l)$  regardless of their antenna port  $p$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70.

### 6.10.3.2 Mapping to resource elements

In a physical resource block with frequency-domain index  $n_{\text{PRB}}$  assigned for the corresponding PDSCH transmission, the reference signal sequence  $r(m)$  shall be mapped to complex-valued modulation symbols  $a_{k,l}^{(p)}$  with  $p=5$  in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r(3 \cdot l' \cdot N_{\text{RB}}^{\text{PDSCH}} + m')$$

$$k = (k') \bmod N_{\text{sc}}^{\text{RB}} + N_{\text{sc}}^{\text{RB}} \cdot n_{\text{PRB}}$$

$$k' = \begin{cases} 4m' + v_{\text{shift}} & \text{if } l \in \{2, 3\} \\ 4m' + (2 + v_{\text{shift}}) \bmod 4 & \text{if } l \in \{5, 6\} \end{cases}$$

$$l = \begin{cases} 3 & l' = 0 \\ 6 & l' = 1 \\ 2 & l' = 2 \\ 5 & l' = 3 \end{cases}$$

$$l' = \begin{cases} 0, 1 & \text{if } n_s \bmod 2 = 0 \\ 2, 3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0, 1, \dots, 3N_{\text{RB}}^{\text{PDSCH}} - 1$$

...

"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of  
 subcarriers are received in at least one of the time slots;"

where  $m'$  is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

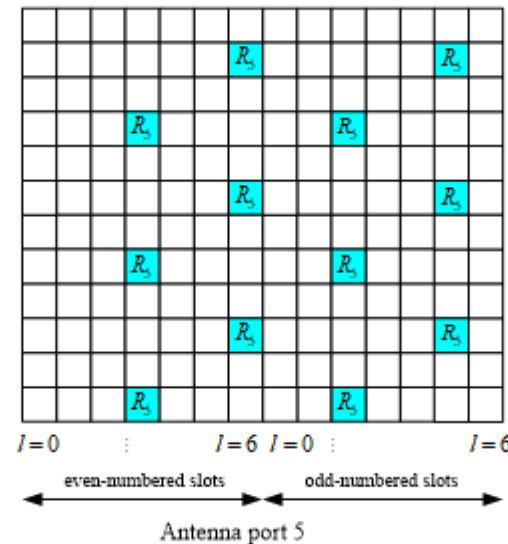
The cell-specific frequency shift is given by  $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 3$ .

The mapping shall be in increasing order of the frequency-domain index  $n_{\text{PRB}}$  of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity  $N_{\text{RB}}^{\text{PDSCH}}$  denotes the bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix.

Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix.

The notation  $R_p$  is used to denote a resource element used for reference signal transmission on antenna port  $p$ .



**Figure 6.10.3.2-1: Mapping of UE-specific reference signals (normal cyclic prefix)**

See e.g., 3GPP TS 36.211 V8.9.0 at pg.71-72



"at least one antenna; and a receiver; and the at least one antenna and the receiver are configured to:  
 receive first pilots of a first type on a first plurality of subcarriers, wherein the first pilots are cell-specific pilots; and  
 receive second pilots of a second type and data on a second plurality of subcarriers, wherein the first plurality of subcarriers and the second plurality of  
 subcarriers are received in at least one of the time slots;"

### 8.2.2 UE-Specific Reference Signals in Release 8

In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE.

A typical usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs. For example, rather than using the physical antennas used for transmission of the other (cell-specific) antenna ports, the eNodeB may use a correlated array of physical antenna elements to generate a narrow beam in the direction of a particular UE. Such a beam will experience a different channel response between the eNodeB and UE, thus requiring the use of UE-specific RSs to enable the UE to demodulate the beamformed data coherently. The use of UE-specific beamforming is discussed in more detail in Section 11.2.2.3.

As identified in [11], the structure shown in Figure 8.4 (for the normal CP) has been chosen because there is no collision with the cell specific RSs, and hence the presence of UE-specific RSs does not affect features related to the cell-specific RSs. The UE-specific RSs have a similar pattern to that of the cell-specific RSs, which allows a UE to re-use similar channel estimation algorithms. The density is half that of the cell-specific RS, hence minimizing the overhead. Unlike the cell-specific RSs, the sequence for the UE-specific RSs is only reinitialized at the start of each subframe, as the number of REs to which the sequence is mapped in one OFDM symbol may be very small (in the event of a small number of RBs being transmitted to a UE). The initialization depends on the UE's identity.

The corresponding pattern for use in case of the extended CP being configured in a cell can be found in [6, Section 6.10.3.2].

See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2<sup>nd</sup> Edition pg. 171.

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

At least some of the first or second plurality subcarriers used to receive the first or second pilots by Ford's Accused Products are beamformed. *E.g.*,

For example, one of the usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs via the second plurality of subcarriers.

### 5.3 Transport Channels

The physical layer offers information transfer services to MAC and higher layers. The physical layer transport services are described by *how* and with what characteristics data are transferred over the radio interface. An adequate term for this is "Transport Channel".

...

Downlink transport channel types are:

1. **Broadcast Channel (BCH)** characterised by:

- fixed, pre-defined transport format;
- requirement to be broadcast in the entire coverage area of the cell.

2. **Downlink Shared Channel (DL-SCH)** characterised by:

- support for HARQ;
- support for dynamic link adaptation by varying the modulation, coding and transmit power;
- possibility to be broadcast in the entire cell;
- possibility to use beamforming;

...

See e.g., 3GPP TS 36.300 V8.12.0 at pg. 30.

In LTE, subcarriers are beam-formed through precoding.

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

### 6.3.4 Precoding

The precoder takes as input a block of vectors  $x(i) = [x^{(0)}(i) \dots x^{(v-1)}(i)]^T$ ,  $i = 0, 1, \dots, M_{\text{symb}}^{\text{layer}} - 1$  from the layer mapping and generates a block of vectors  $y(i) = [\dots y^{(p)}(i) \dots]^T$ ,  $i = 0, 1, \dots, M_{\text{symb}}^{\text{ap}} - 1$  to be mapped onto resources on each of the antenna ports, where  $y^{(p)}(i)$  represents the signal for antenna port  $p$ .

#### 6.3.4.1 Precoding for transmission on a single antenna port

For transmission on a single antenna port, precoding is defined by

$$y^{(p)}(i) = x^{(0)}(i)$$

where  $p \in \{0, 4, 5\}$  is the number of the single antenna port used for transmission of the physical channel and  $i = 0, 1, \dots, M_{\text{symb}}^{\text{ap}} - 1$ ,  $M_{\text{symb}}^{\text{ap}} = M_{\text{symb}}^{\text{layer}}$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 52.

"wherein at least some subcarriers of the first plurality of subcarriers or the second plurality of subcarriers are beam-formed; and

### **8.2.2 UE-Specific Reference Signals in Release 8**

In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE.

A typical usage of the UE-specific RSs is to enable beamforming of the data transmissions to specific UEs. For example, rather than using the physical antennas used for transmission of the other (cell-specific) antenna ports, the eNodeB may use a correlated array of physical antenna elements to generate a narrow beam in the direction of a particular UE. Such a beam will experience a different channel response between the eNodeB and UE, thus requiring the use of UE-specific RSs to enable the UE to demodulate the beamformed data coherently. The use of UE-specific beamforming is discussed in more detail in Section 11.2.2.3.

As identified in [11], the structure shown in Figure 8.4 (for the normal CP) has been chosen because there is no collision with the cell specific RSs, and hence the presence of UE-specific RSs does not affect features related to the cell-specific RSs. The UE-specific RSs have a similar pattern to that of the cell-specific RSs, which allows a UE to re-use similar channel estimation algorithms. The density is half that of the cell-specific RS, hence minimizing the overhead. Unlike the cell-specific RSs, the sequence for the UE-specific RSs is only reinitialized at the start of each subframe, as the number of REs to which the sequence is mapped in one OFDM symbol may be very small (in the event of a small number of RBs being transmitted to a UE). The initialization depends on the UE's identity.

The corresponding pattern for use in case of the extended CP being configured in a cell can be found in [6, Section 6.10.3.2].

See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2<sup>nd</sup> Edition pg. 171.

U.S. Patent No. 10,965,512: Claim 15(d)

"the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;

The receiver of Ford's Accused Products is further configured to recover the data using channel estimates and cell-specific information using the pilots. *E.g.*,

The UE is further configured to recover the data using channel estimates from at least the second pilots and recover cell-specific information using the cell-specific pilots.

For example, the LTE UE uses the UE-specific reference signals embedded in the received PRBs to derive the channel estimation for demodulating the data in the corresponding PDSCH resource blocks.

### 6.10.3 UE-specific reference signals

UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements  $(k, l)$  in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair  $(k, l)$  regardless of their antenna port  $p$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70.

### 8.2.2 UE-Specific Reference Signals in Release 8

In Release 8 of LTE, UE-specific RSs may be transmitted in addition to the cell-specific RSs described above if the UE is configured (by higher-layer RRC signalling) to receive its downlink PDSCH data in transmission mode 7 (see Section 9.2.2.1). The UE-specific RSs are embedded only in the RBs to which the PDSCH is mapped for those UEs. If UE-specific RSs are transmitted, the UE is expected to use them to derive the channel estimate for demodulating the data in the corresponding PDSCH RBs. The same precoding is applied to the UE-specific RSs as to the PDSCH data symbols, and therefore there is no need for signalling to inform the UE of the precoding applied. Thus the UE-specific RSs are treated as being transmitted using a distinct antenna port (number 5), with its own channel response from the eNodeB to the UE.

See e.g., LTE - The UMTS Long Term Evolution - FROM THEORY TO PRACTICE - 2<sup>nd</sup> Edition pg. 171.



U.S. Patent No. 10,965,512: Claim 15(d)

"the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

The LTE UE recovers cell-specific information, such as the cell ID, using the cell-specific pilots. The Cell ID ( $N_{ID}^{cell}$ ) is used for generating the cell-specific reference signal sequence.

#### 6.10.1.1 Sequence generation

The reference-signal sequence  $r_{l,n_s}(m)$  is defined by

$$r_{l,n_s}(m) = \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m)) + j \frac{1}{\sqrt{2}}(1 - 2 \cdot c(2m+1)), \quad m = 0, 1, \dots, 2N_{RB}^{\max, DL} - 1$$

where  $n_s$  is the slot number within a radio frame and  $l$  is the OFDM symbol number within the slot. The pseudo-random sequence  $c(i)$  is defined in Section 7.2. The pseudo-random sequence generator shall be initialised with  $c_{init} = 2^{10} \cdot (7 \cdot (n_s + 1) + l + 1) \cdot (2 \cdot N_{ID}^{cell} + 1) + 2 \cdot N_{ID}^{cell} + N_{CP}$  at the start of each OFDM symbol where

$$N_{CP} = \begin{cases} 1 & \text{for normal CP} \\ 0 & \text{for extended CP} \end{cases}$$

See e.g., 3GPP TS 36.211 V8.9.0 at pgs.65-66.

The LTE cell-specific reference signal is also used to recover cell-specific information from the *MasterInformationBlock*, which is transmitted via the broadcast channel (BCH). The cell-specific reference signal is used, *inter alia*, to estimate the channel corresponding to the center part of the carrier where the BCH is transmitted.

— ***MasterInformationBlock***

The *MasterInformationBlock* includes the system information transmitted on BCH.

U.S. Patent No. 10,965,512: Claim 15(d)

"the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

Signalling radio bearer: N/A

RLC-SAP: TM

Logical channel: BCCH

Direction: E-UTRAN to UE

### ***MasterInformationBlock***

-- ASN1START

```
MasterInformationBlock ::= SEQUENCE {
    dl-Bandwidth             ENUMERATED {
                                n6, n15, n25, n50, n75, n100},
    phich-Config             PHICH-Config,
    systemFrameNumber        BIT STRING (SIZE (8)),
    spare                    BIT STRING (SIZE (10))
}
```

-- ASN1STOP

### ***MasterInformationBlock field descriptions***

#### ***dl-Bandwidth***

Parameter: transmission bandwidth configuration,  $N_{RB}$  in downlink, see TS 36.101 [42, table 5.6-1]. n6 corresponds to 6 resource blocks, n15 to 15 resource blocks and so on.

#### ***systemFrameNumber***

Defines the 8 most significant bits of the SFN, see TS 36.211 [21, 6.6.1]. The 2 least significant bits of the SFN are acquired implicitly in the P-BCH decoding, i.e. timing of 40ms P-BCH TTI indicates 2 least significant bits (within 40ms P-BCH TTI, the first radio frame: 00, the second radio frame: 01, the third radio frame: 10, the last radio frame: 11).

See e.g., 3GPP TS 36.331 V8.21.0 at pgs.85-86.

ceiving neighbor-cell 4G, LTE-ADVANCED PRO AND THE ROAD TO 5G

### **6.2.1. Cell-Specific Reference Signals**

U.S. Patent No. 10,965,512: Claim 15(d)

"the receiver is further configured to:

recover the data using channel estimates from at least the second pilots; and recover cell-specific information using the cell-specific pilots;"

In general, the values of the reference symbols vary between different reference-symbol positions and also between different cells. Thus, a CRS can be seen as a two-dimensional cell-specific sequence. The period of this sequence equals one 10ms frame. Furthermore, regardless of the cell bandwidth, the reference-signal sequence is defined assuming the maximum possible LTE carrier bandwidth corresponding to 110 resource blocks in the frequency domain. Thus, the basic reference-signal sequence has a length of 8800 symbols.<sup>2</sup> For cell bandwidths less than the maximum possible value, only the reference symbols within that bandwidth are actually transmitted. The reference symbols in the center part of the band will therefore be the same, regardless of the actual cell bandwidth. This allows for the device to estimate the channel corresponding to the center part of the carrier, where, for example, the basic system information of the cell is transmitted on the BCH transport channel, without knowing the cell bandwidth. Information about the actual cell bandwidth, measured as number of resource blocks, is then provided on the BCH.

See e.g., 4G, LTE ADVANCED PRO AND THE ROAD TO 5G, Third Edition, pg. 104



U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots.

The second type of pilots used with Ford's Accused Products are different than the first type of pilots and the first pilots do not interfere with the second pilots. *E.g.*,

For example, cell-specific reference signals, the first pilots, are different than the UE-specific reference signals, second pilots.

## 6.10 Reference signals

Three types of downlink reference signals are defined:

- Cell-specific reference signals, associated with non-MBSFN transmission
- MBSFN reference signals, associated with MBSFN transmission
- UE-specific reference signals

There is one reference signal transmitted per downlink antenna port.

See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

The UE-specific reference signals are not transmitted in resource elements in which other physical signals, such as the cell-specific reference signal, are transmitted. Thus, they do not interfere.

### 6.10.3 UE-specific reference signals

UE-specific reference signals are supported for single-antenna-port transmission of PDSCH and are transmitted on antenna port 5. UE specific reference signals are present and are a valid reference for PDSCH demodulation only if the PDSCH transmission is associated with the corresponding antenna port according to Section 7.1 of [4]. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped. The UE-specific reference signal is not transmitted in resource elements  $(k, l)$  in which one of the physical channels or physical signals other than UE-specific reference signal defined in 6.1 are transmitted using resource elements with the same index pair  $(k, l)$  regardless of their antenna port  $p$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg. 70.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

**6.10.3.2 Mapping to resource elements**

In a physical resource block with frequency-domain index  $n_{\text{PRB}}$  assigned for the corresponding PDSCH transmission, the reference signal sequence  $r(m)$  shall be mapped to complex-valued modulation symbols  $a_{k,l}^{(p)}$  with  $p=5$  in a subframe according to:

Normal cyclic prefix:

$$a_{k,l}^{(p)} = r(3 \cdot l' \cdot N_{\text{RB}}^{\text{PDSCH}} + m')$$

$$k = (k') \bmod N_{\text{sc}}^{\text{RB}} + N_{\text{sc}}^{\text{RB}} \cdot n_{\text{PRB}}$$

$$k' = \begin{cases} 4m' + v_{\text{shift}} & \text{if } l \in \{2, 3\} \\ 4m' + (2 + v_{\text{shift}}) \bmod 4 & \text{if } l \in \{5, 6\} \end{cases}$$

$$l = \begin{cases} 3 & l' = 0 \\ 6 & l' = 1 \\ 2 & l' = 2 \\ 5 & l' = 3 \end{cases}$$

$$l' = \begin{cases} 0, 1 & \text{if } n_s \bmod 2 = 0 \\ 2, 3 & \text{if } n_s \bmod 2 = 1 \end{cases}$$

$$m' = 0, 1, \dots, 3N_{\text{RB}}^{\text{PDSCH}} - 1$$

...

where  $m'$  is the counter of UE-specific reference signal resource elements within a respective OFDM symbol of the PDSCH transmission.

The cell-specific frequency shift is given by  $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 3$ .

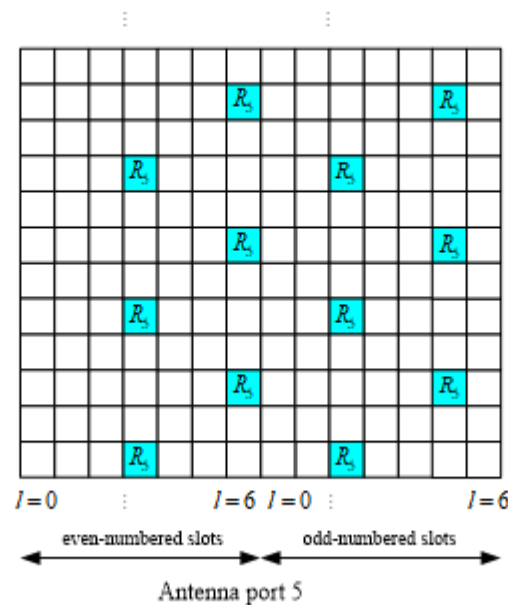
The mapping shall be in increasing order of the frequency-domain index  $n_{\text{PRB}}$  of the physical resource blocks assigned for the corresponding PDSCH transmission. The quantity  $N_{\text{RB}}^{\text{PDSCH}}$  denotes the bandwidth in resource blocks of the corresponding PDSCH transmission.

Figure 6.10.3.2-1 illustrates the resource elements used for UE-specific reference signals for normal cyclic prefix.

Figure 6.10.3.2-2 illustrates the resource elements used for UE-specific reference signals for extended cyclic prefix.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

The notation  $R_p$  is used to denote a resource element used for reference signal transmission on antenna port  $p$ .

See e.g., 3GPP TS 36.211 V8.9.0 at pg.71-72

### 6.10.1 Cell-specific reference signals

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols.

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3.

Cell-specific reference signals are defined for  $\Delta f = 15$  kHz only.

See e.g., 3GPP TS 36.211 V8.9.0 at pg.65.

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

**6.10.1.2 Mapping to resource elements**

The reference signal sequence  $r_{i,n_s}(m)$  shall be mapped to complex-valued modulation symbols  $a_{k,l}^{(p)}$  used as reference symbols for antenna port  $p$  in slot  $n_s$  according to

$$a_{k,l}^{(p)} = r_{i,n_s}(m')$$

where

$$k = 6m + (v + v_{\text{shift}}) \bmod 6$$

$$l = \begin{cases} 0, N_{\text{symbol}}^{\text{DL}} - 3 & \text{if } p \in \{0,1\} \\ 1 & \text{if } p \in \{2,3\} \end{cases}$$

$$m = 0, 1, \dots, 2 \cdot N_{\text{RB}}^{\text{DL}} - 1$$

$$m' = m + N_{\text{RB}}^{\text{max,DL}} - N_{\text{RB}}^{\text{DL}}$$

The variables  $v$  and  $v_{\text{shift}}$  define the position in the frequency domain for the different reference signals where  $v$  is given by

$$v = \begin{cases} 0 & \text{if } p = 0 \text{ and } l = 0 \\ 3 & \text{if } p = 0 \text{ and } l \neq 0 \\ 3 & \text{if } p = 1 \text{ and } l = 0 \\ 0 & \text{if } p = 1 \text{ and } l \neq 0 \\ 3(n_s \bmod 2) & \text{if } p = 2 \\ 3 + 3(n_s \bmod 2) & \text{if } p = 3 \end{cases}$$

The cell-specific frequency shift is given by  $v_{\text{shift}} = N_{\text{ID}}^{\text{cell}} \bmod 6$ .

Resource elements  $(k, l)$  used for reference signal transmission on any of the antenna ports in a slot shall not be used for any transmission on any other antenna port in the same slot and set to zero.

Figures 6.10.1.2-1 and 6.10.1.2-2 illustrate the resource elements used for reference signal transmission according to the above definition. The notation  $R_p$  is used to denote a resource element used for reference signal transmission on antenna port  $p$ .

U.S. Patent No. 10,965,512: Claim 15(e)

" wherein the second type is different than the first type and wherein the first pilots do not interfere with the second pilots."

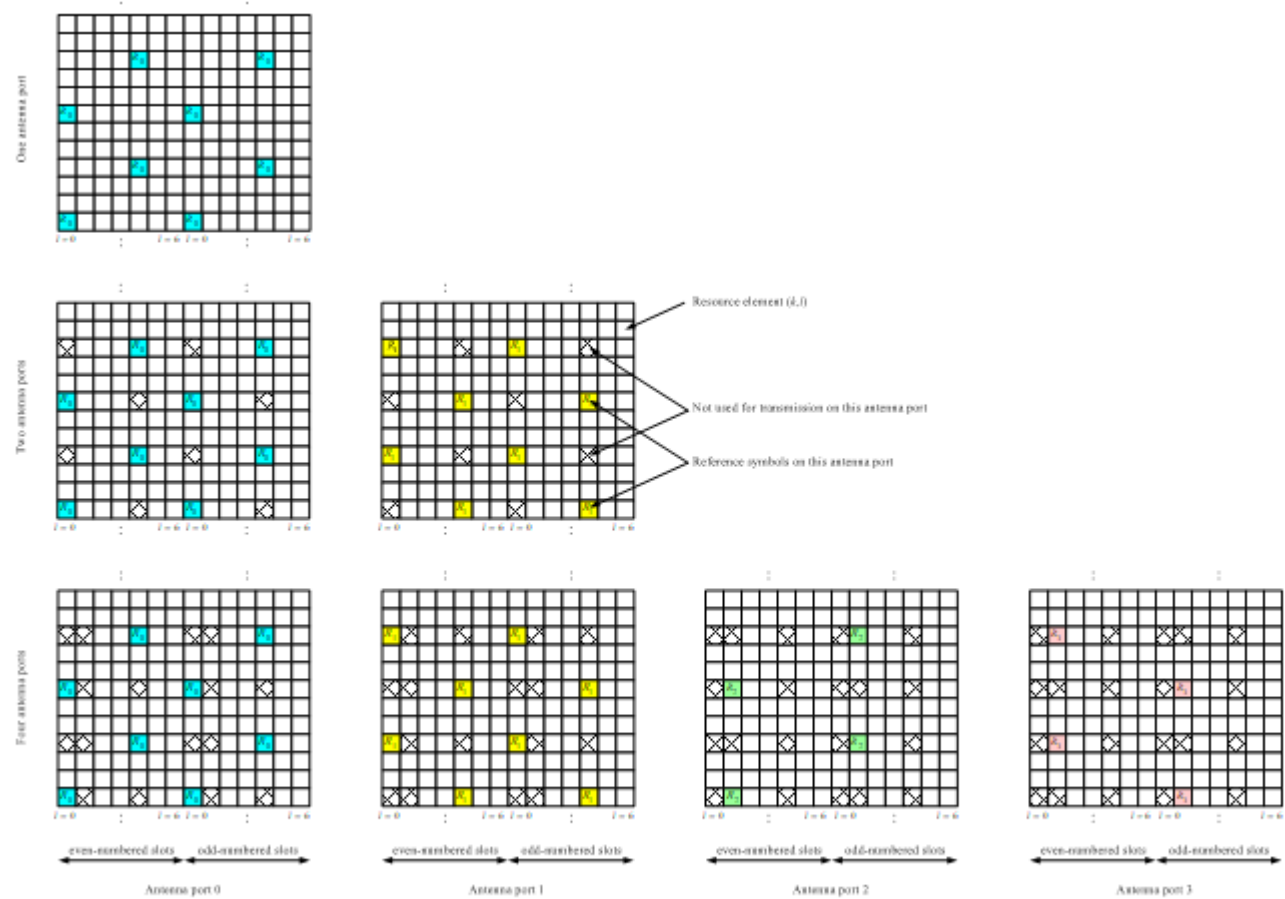


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).

See e.g., 3GPP TS 36.211 V8.9.0 at pg.66-67.